



US009543456B1

(12) **United States Patent**
Welser et al.

(10) **Patent No.:** **US 9,543,456 B1**
(45) **Date of Patent:** **Jan. 10, 2017**

(54) **MULTIJUNCTION SOLAR CELL
EMPLOYING EXTENDED
HETEROJUNCTION AND STEP GRADED
ANTIREFLECTION STRUCTURES AND
METHODS FOR CONSTRUCTING THE
SAME**

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

(71) Applicant: **Magnolia Solar, Inc.**, Woburn, MA
(US)

4,583,822 A 4/1986 Southwell
5,496,415 A 3/1996 Barnham
7,202,411 B1 4/2007 Wernsman

(Continued)

(72) Inventors: **Roger E. Welser**, Providence, RI (US);
Ashok K. Sood, Brookline, MA (US)

FOREIGN PATENT DOCUMENTS

(73) Assignee: **Magnolia Solar, Inc.**, Woburn, MA
(US)

EP 1100168 A1 5/2001

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

OTHER PUBLICATIONS

(21) Appl. No.: **14/547,055**

Alemu, et al., "Dependence of Device Performance on Carrier
Escape Sequence in Multi-quantum-Well p-i-n Solar Cells", "Jour-
nal of Applied Physics", May 4, 2006, pp. 084506-1-084506-5, vol.
99, No. 084506, Publisher: American Institute of Physics, Published
in: US.

(22) Filed: **Nov. 18, 2014**

(Continued)

Related U.S. Application Data

Primary Examiner — Eli Mekhlin

(63) Continuation of application No. 12/719,811, filed on
Mar. 8, 2010, now Pat. No. 8,895,838.

(74) *Attorney, Agent, or Firm* — Loginov & Associates,
PLLC; William A. Loginov

(60) Provisional application No. 61/293,469, filed on Jan.
8, 2010.

(57) **ABSTRACT**

(51) **Int. Cl.**
H01L 31/00 (2006.01)
H01L 31/0216 (2014.01)
H01L 31/0725 (2012.01)
H01L 31/0735 (2012.01)
H01L 31/18 (2006.01)

Material and antireflection structure designs and methods of
manufacturing are provided that produce efficient photovol-
taic power conversion from single- and multi-junction
devices. Materials of different energy gap are combined in
the depletion region of at least one of the semiconductor
junctions. Higher energy gap layers are positioned to reduce
the diode dark current and enhance the operating voltage by
suppressing both carrier injections across the junction and
recombination rates within the junction. Step-graded anti-
reflection structures are placed above the active region of the
device in order to increase the photocurrent.

(52) **U.S. Cl.**
CPC **H01L 31/02168** (2013.01); **H01L 31/0725**
(2013.01); **H01L 31/0735** (2013.01); **H01L**
31/184 (2013.01); **H01L 31/1844** (2013.01)

1 Claim, 8 Drawing Sheets

